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PREVALENCE OF CHRONIC RESPIRATORY DISEASE IN CHATTANOOGA: EFFECTS OF COMMUNITY EXPOSURE TO NITROGEN OXIDES

by

Benjamin Carpenter, W. Kenneth Poole
and Donald W. Jackson

Statistics Research Division
Research Triangle Institute

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Final Report

SU-572

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the
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under

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June 25, 1971

PREVALENCE OF CHRONIC RESPIRATORY ILLNESS

IN CHATTANOOGA:

EFFECTS OF COMMUNITY EXPOSURE TO NITROGEN OXIDES

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16. Abstracts
The prevalence of chronic respiratory illness among 3,500 parents of high school students was studied in Chattanooga during the last quarter of 1970. Data were obtained from parents of students in four senior high schools, the neighborhoods of which had an exposure gradient to atmospheric nitrogen dioxide. The smoking habits of respondents were measured by the usual questionnaire techniques and by carbon monoxide concentrations in alveolar breath samples. Lung function was measured by one second forced expiratory volume (FEV) tests. Chronic respiratory illness was classified using a seven scale severity rating. Breath carbon monoxide levels were correlated with smoking habits, FEV and severity rating of chronic respiratory illness. FEV test results, corrected for height, age, sex, race, and CO, were significantly lower among sample parents living in the high-nitrogen dioxide exposure area. Residents of that area did not show a significantly higher prevalence of chronic respiratory illness.

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Preface

This is the final report for Contract CPA-70-135 with the Office of Air Programs, Environmental Protection Agency. Under this contract, the Research Triangle Institute (RTI) determined the prevalence of chronic respiratory illness (CRI) among parents of high school students in areas of the Chattanooga, Tennessee SMSA who received varying levels of exposure to nitrogen dioxide (NO_2). Data obtained were analyzed to determine whether the high NO_2 areas showed increased prevalence of CRI, or decreased lung function, or both.

RTI conducted the study in close collaboration with Dr. Carl Shy, who served as the project officer. Equipment for physical tests and air quality data were provided by EPA.

It is anticipated that this report will be considered for publication. The main body of the report has been prepared for this purpose with title and authors indicated on the abstract page. It was felt that certain additional details should be provided for APCO's records and use. Therefore, the appendixes of the report serve to document the care taken in determining boundaries of study areas, in questionnaire development, and in conducting the field survey.

The air quality levels presented in Figure 2 of this report are uncorrected field measures. They serve for comparison pending the development of a correction factor. The factor required to convert to actual values is under investigation and will not be available until after expiration of the contract with RTI.

PREVALENCE OF CHRONIC RESPIRATORY DISEASE IN CHATTANOOGA:

EFFECTS OF COMMUNITY EXPOSURE TO NITROGEN OXIDES

by

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The prevalence of chronic respiratory illness among 3,500 parents of high school students was studied in Chattanooga during the last quarter of 1970. Data were obtained from parents of students in four senior high schools, the neighborhoods of which had an exposure gradient to atmospheric nitrogen dioxide. The smoking habits of respondents were measured by the usual questionnaire techniques and by carbon monoxide concentrations in alveolar breath samples. Lung function was measured by one second forced expiratory volume (FEV) tests. Chronic respiratory illness was classified using a seven scale severity rating. Breath carbon monoxide levels were correlated with smoking habits, FEV and severity rating of chronic respiratory illness. FEV test results, corrected for height, age, sex, race, and CO, were significantly lower among sample parents living in the high-nitrogen dioxide exposure area. Residents of that area did not show a significantly higher prevalence of chronic respiratory illness.

PREVALENCE OF CHRONIC RESPIRATORY DISEASE IN CHATTANOOGA: EFFECTS OF EXPOSURE TO NITROGEN OXIDES

I. INTRODUCTION

Previous epidemiologic studies, by the National Air Pollution Control Administration, have shown an increase in the incidence of acute respiratory disease among children who are exposed to an environment containing increased concentrations of nitrogen dioxide (NO_2).[1] The relationship between lower respiratory infections and NO_2 exposure has not been studied previously in adult humans but British studies revealed increased rates of such infections among infants exposed to sulfur oxides and particulate pollution.[2,3]

In animal studies of the effect of NO_2 upon host defense mechanism, rats exposed to 2 ppm NO_2 for 33 weeks showed bronchial epithelial abnormalities. However, those exposed to 0.8 ppm of NO_2 for 33 months showed no epithelial changes.[4]

Valand reported that 25 ppm NO_2 inhibited alveolar macrophage interferon production and facilitated infection with parainfluenza.[5] Animals given acute and chronic exposure to NO_2 showed reduced resistance to infection produced by a respiratory challenge with airborne K. pneumoniae.[6] Buckley, on the other hand, reported that exposure to 37 ppm NO_2 for 2 to 30 days decreased mortality and rate of infection in mice exposed to mouse adapted PR8 influenza virus.[7]

The study described here compares the prevalence of chronic respiratory illness among parents in families living in areas with varying degrees of NO_2 air pollution. Also compared are pulmonary function tests. The comparisons are corrected for age, sex, race, and smoking habits. Alveolar carbon monoxide levels were employed as an additional indicator of the effects of smoking.

II. MATERIALS AND METHODS

II - 1 Study Area

The manufacture of trinitro-toluene (TNT) near Chattanooga, Tennessee provided the specific exposure to nitrogen oxides (NO_2) needed for the conduct of this study. During the Korean and Second World Wars a substantial proportion of all TNT made in the United States was produced by a plant located northeast of Chattanooga, Tennessee, in rural Hamilton County. The plant was reopened in April, 1966 to supply munitions for use in Vietnam. By then the facility was bordered by upper-middle-class suburbs whose residents soon began to complain about the presence of fumes. Air quality monitoring revealed elevated levels of NO_2, a pollutant usually associated with automotive and industrial emissions.

There were two areas sufficiently similar socio-economically to the area of exposure and sufficiently removed from the area to serve as controls for this study.

In all, four areas in Greater Chattanooga were selected: a high NO_2 exposure area surrounding the ammunition plant, an intermediate NO_2 exposure area seven miles southwest of the plant and separated from it by low ridges, a low NO_2 exposure area located northwest of the plant across the Tennessee River, and a high suspended particulates area in downtown Chattanooga. These areas are shown in Figure 1, which also shows the location of air monitoring stations. Monitoring data consisting of 24-hour suspended particulate matter, suspended nitrates and sulfates, and NO_2 gas concentrations were measured every four days from October 29, 1968 to April 26, 1969.[8/] The NO_2 samples were collected by gas bubbler and analyzed by the Jacobs-Hochheisser method. As shown in Table 1, mean integrated 24-hour NO_2 levels were 152 $\mu g/m^3$ in the High Exposure Area, 118 $\mu g/m^3$ in Control Area 1, and 81 $\mu mg/m^3$ in Control Area 2. The nitrate fraction of total suspended particulates was 6 $\mu g/m^3$ in the High Exposure Area, 3 in Control Area 1, and 2 in Control Area 2. Total suspended particular concentrations were similar in all three of these areas, but higher in the "high particulate" area. Soiling index was lower in the high-NO_2 area.

The monthly average NO_2 levels found in the three main study areas over an eight month period that included this study are shown in Figure 2.[8/]

Average levels of NO_2 in non-urban air have been shown to be 10.6 $\mu g/m^3$.[9/]

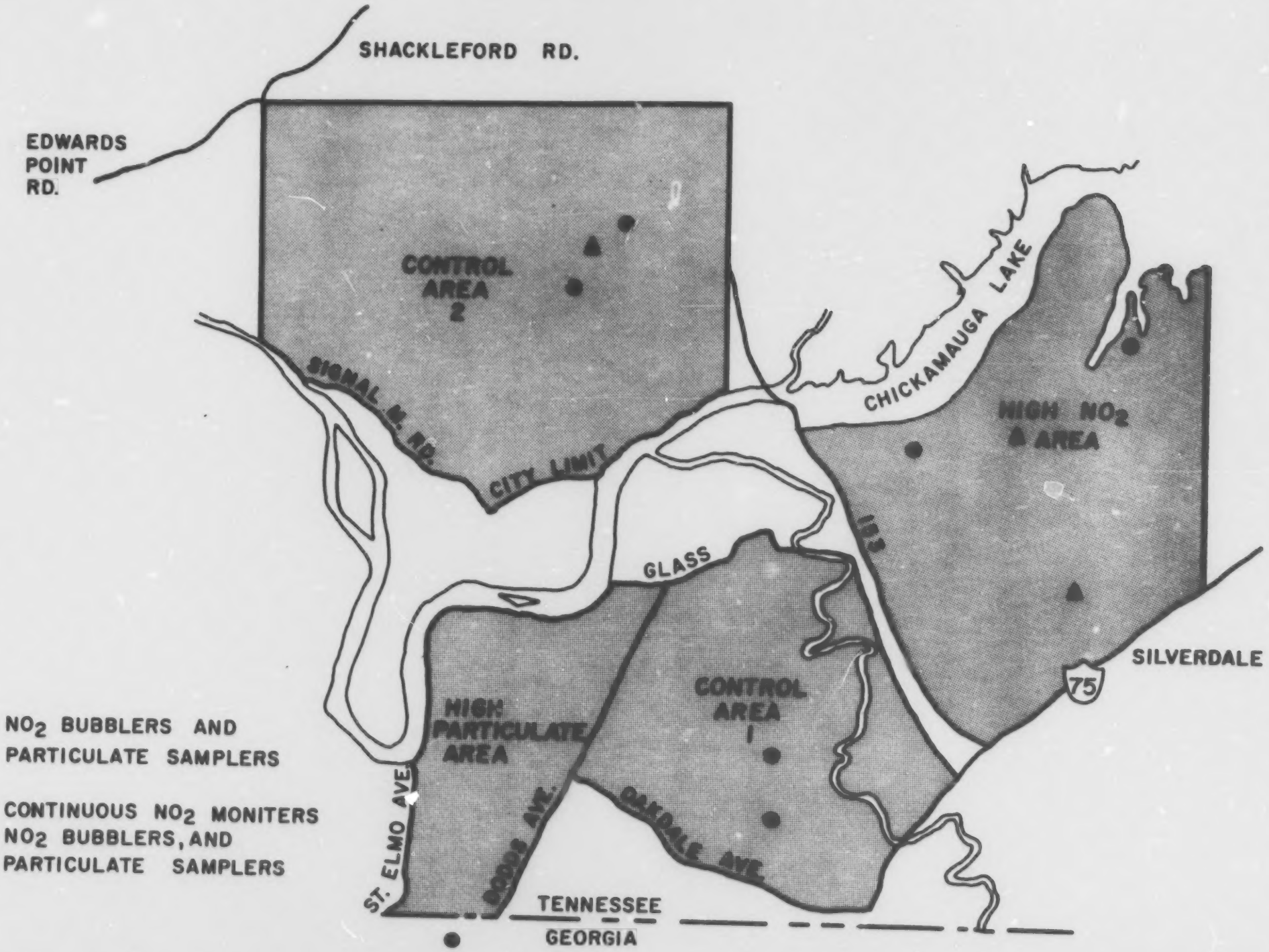

Figure 1. Study Areas in Greater Chattanooga.

TABLE I

Mean Levels of Air Pollutants

Mean Concentration, micrograms/cubic meter[a]

Study Area	NO_2	Suspended Nitrates	Suspended Sulfates	Total Suspended Particulates	Soiling Index[b] cohs/1000 lin. ft.
High NO_2 Area	156	6	12	81	0.86
Control Area 1 (Intermediate NO_2 Area)	118	3	10	72	1.39
Control Area 2 (Low NO_2 Area)	81	2	10	62	1.23
High Particulate Area	103	3	11	99	2.09

a = Arithmetic mean of all samples collected

b = Four hour measurements

II-2 The Population Studied

It is generally recognized that the prevalence of chronic respiratory illness in the human population varies with age. It tends to be fairly stable in the age groups 35-49, and to rise rather sharply in older age groups.[10/] Thus a significant increase due to exposure to some air pollutant might be more readily detected if the 35-49 age group were selected for study. This age group was selected by choosing the parents of children in grades 10, 11, and 12 of high school as the study population. Previous studies indicate that such groups may show about nine percent frequency of positive spirometry tests among males, and about 15 percent among females.

A five percent higher average positive response among smokers has been reported.[10/] This and the age effect point up the importance of

recognizing the existence of several factors, each influencing the prevalence of pulmonary disease.

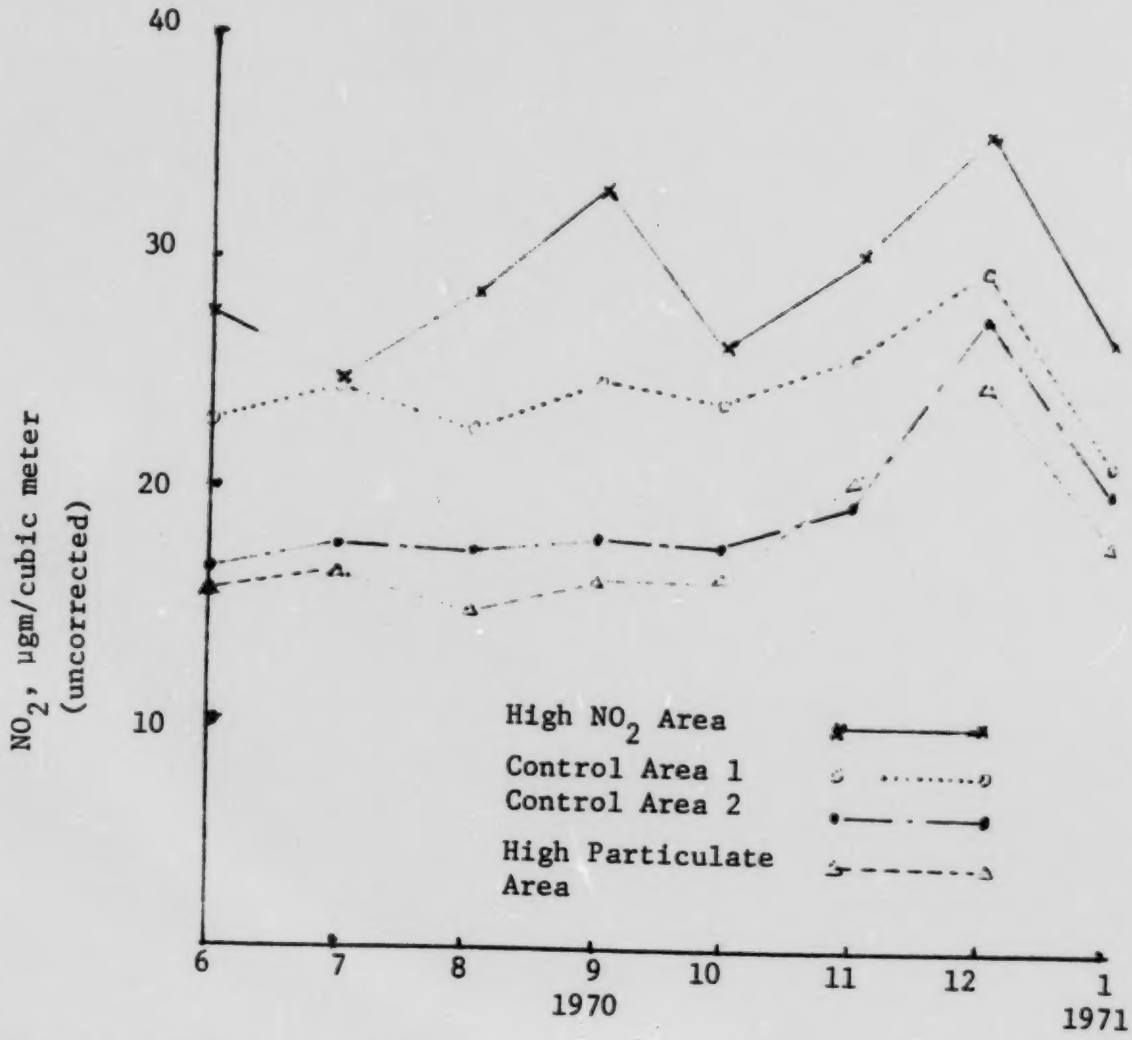

Figure 2. Average Daily NO_2 Concentration by Month from June 1970 to January 1971.

II-3 Sampling Procedure

Four senior high schools were located within the selected study areas. Two were in the High-NO_2 Area, one was in Control Area 1, and one was in Control Area 2. The study was conducted over a period of ten weeks in October, November, and December 1970. A four-phase survey was conducted at each school in turn. In Phase 1, all parents of enrolled students were

requested to participate by coming to the school for questionnaire administration and physiological testing. A self-selective sample of n_1 persons resulted. In Phase 2, a probability sample of approximately 50 households (about 100 persons) from each school's non-respondents were interviewed personally. Both questionnaire and physiological data were obtained. In Phase 3 questionnaires were mailed to all Phase 1 non-respondents not included in Phase 2. A self-selective sample of n_3 respondents to the questionnaire only resulted (no physiological data). In Phase 4, a probability sample of approximately 100 (n_4) Phase 3 non-respondents were interviewed by telephone. Questionnaire data only were obtained. Figure 3 is a diagram of the sampling selection process for each school. The field work began October 5, 1970, and was completed December 19, 1970.*

II-4 Test Procedures

The presence of chronic respiratory illness (CRI) was detected by administering a screening questionnaire, which provided (1) data for categorization of the individual, (2) prescreening questions to establish whether the screenee was in a medical care program for chronic respiratory illness or a related serious disease, and (3) symptom questions concerning cough, phlegm, and shortness of breath. Diagnostic questions were patterned after the British Medical Research Council questionnaire.[11/] However, persistence of cough or phlegm for as much as three months was counted as a major symptom, whether it occurred in the winter as required by the British Medical Research Council questionnaire, or in any other time of year.**

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*A detailed account of Field Procedures is given in Appendix C.

**The complete questionnaire is shown in Appendix B.

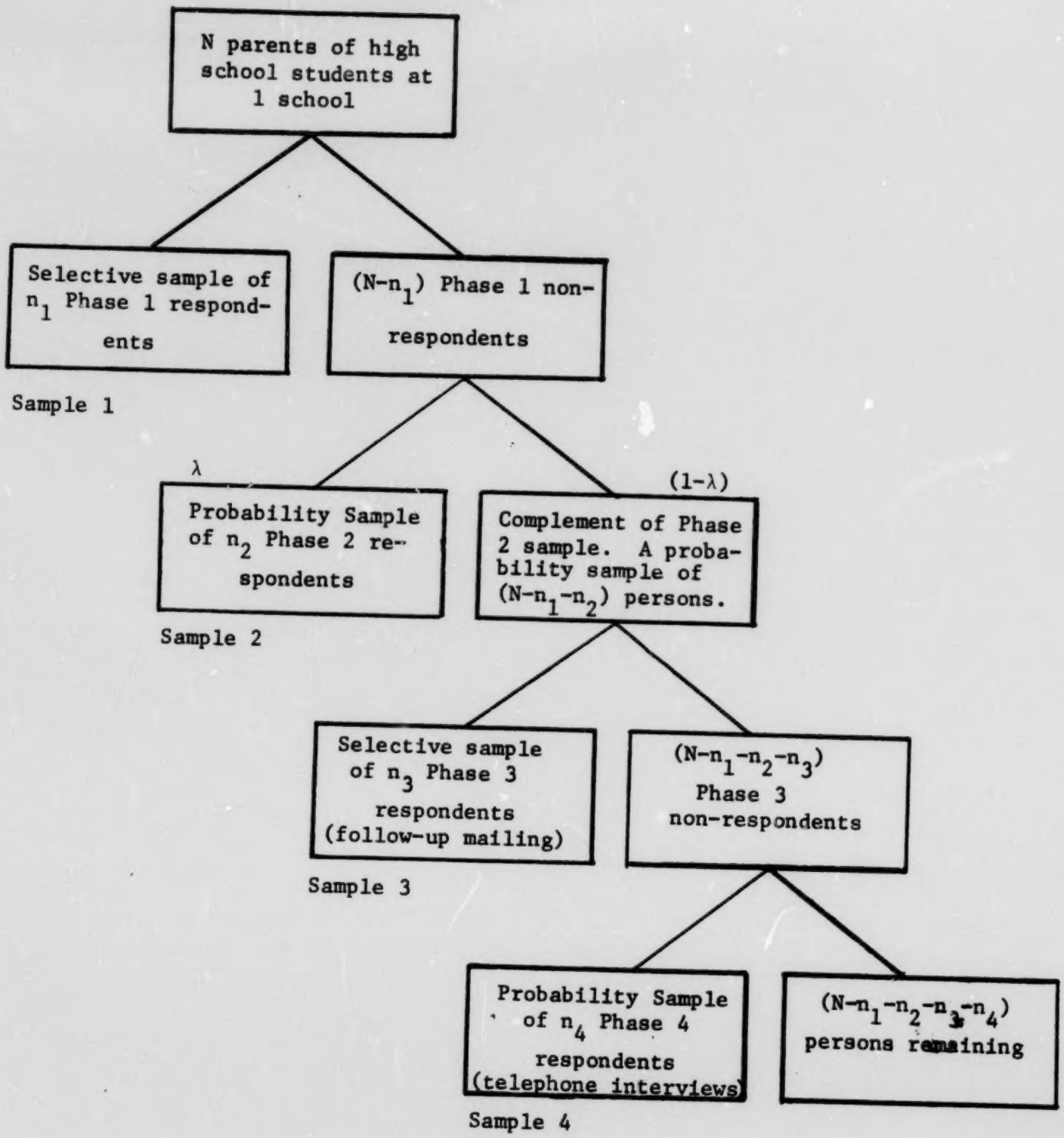
N parents of high school students at 1 school
Selective sample of n_1 Phase 1 respondents
Sample 1
$(N-n_1)$ Phase 1 non-respondents
λ
Probability Sample of n_2 Phase 2 respondents
Sample 2
$(1-\lambda)$
Complement of Phase 2 sample. A probability sample of $(N-n_1-n_2)$ persons.
Selective sample of n_3 Phase 3 respondents (follow-up mailing)
Sample 3
$(N-n_1-n_2-n_3)$ Phase 3 non-respondents
Probability Sample of n_4 Phase 4 respondents (telephone interviews)
Sample 4
$(N-n_1-n_2-n_3-n_4)$ persons remaining

Figure 3. Diagram of Sample Selection from One School.

Each respondent was given a severity rating according to his answers to the questions, as follows:

Rating	Symptoms
1	None
2	cough alone for < 3 months/year
3	phlegm with or without cough for < 3 months/year
4	cough without phlegm for ≥ 3 months/year
5	phlegm without cough for ≥ 3 months/year
6	cough and phlegm for ≥ 3 months/year
7	cough and phlegm for ≥ 3 months/year and shortness of breath.

These ratings were utilized in determining the effect of NO_2 on CRI symptom severity. However, to determine the prevalence of CRI in sub-populations, those respondents who showed a severity rating of four or greater were simply classified as having CRI, while those with a rating of three or less were classified as not having CRI. This is consistent with most studies previously reported.

The usual basis for measuring the intensity of the smoking habit is the smoking rate, or number of cigarettes smoked per day. While this approach was utilized in this study, the carbon monoxide (CO) concentration of the respondents alveolar breath was also measured.

Breath from the alveoli acquires a CO concentration by equilibration with the carboxyhemoglobin in the blood.[12/] The blood level of carboxy-hemoglobin is itself determined by the concentration of CO to which it is exposed in the alveoli. Thus the CO concentration in the alveolar breath tends to measure the extent of exposure of the smoker's lower respiratory tract to cigarette smoke.

Although the CO taken into the blood during smoking is slowly released after each smoking episode, and therefore the CO concentration in the alveolar breath would decrease with time since the last cigarette, the frequent smoker would tend to build up the blood level again with each cigarette. As a result, the heavier smoker whose smoking habit exposes the lower respiratory tract to products of cigarette combustion should maintain a somewhat fluctuating but always higher blood level of carboxyhemoglobin than the light smoker or the non-smoker.

The CO content of cigarette smoke has been found to be between three and five percent, while for cigar smoke it is between 1.5 and 4.5 percent, and for pipe smoke, about one percent.[13/]

The alveolar breath sample was taken in such a manner as to collect only that portion of the expired breath which had been well into the lungs. After breathing deeply twice, the participant held his next breath for 20 seconds, and then exhaled through a valve which deflected the final portions of the expiration into a sampling bag made of mylar fiber.[14/] Alveolar breath samples were collected in Phases 1 and 2 of this study.

The samples were then analyzed using a Beckman IR 315 L non-dispersive Infrared Analyzer. This instrument responds only to three components of expired air: CO, CO_2, and H_2O. By passing the collected breath samples first through Ascarite and Drierite traps, which absorb CO_2 and H_2O, the instrument was made specific for CO. Each day standard samples of CO in N_2 were passed through the instrument in order to check its stability and calibration. The CO_2 and H_2O absorbers were renewed as required. It was confirmed during the tests that standard CO samples could be confined unchanged in the bags for at least 24 hours.

A one second forced expiratory volume (FEV_1) was performed by each adult in samples Phases 1 nad 2, using a Stead-Wells spirometer. This measurement was repeated until two highest values checked within five percent. It will be referred to simply as FEV in subsequent discussion. The participant's height was recorded so that corrections could be made for the effect of height in the analysis of the data.

III. RESULTS

There were 6,912 eligible parents, of which 3,531, or 51 percent, participated in the study. Table II shows the distribution of the participants according to the area in which they lived. Also shown is the estimated total number of parents living in each study area. The variation in percent participation in the main study areas is not statistically significant.

TABLE II

Distribution of Individuals According to Residence in Study Areas and Participation in the Study

Study Area	Parents Living in Area (Estimated)	Parents Participating	Percent Participating	Standard Deviation *
High NO_2	1529	830	54.3	2.2
High Particulate	132	55	41.8	6.9
Control 1	1824	993	54.4	2.2
Control 2	1552	831	53.5	2.2
Total	5037	2709	53.7	
Outside	1875	822	43.8	1.7
Total	6912	3531	51.1	

* The standard deviations shown here were calculated by means of formula (0), Section IV-5, using $X = 1/W_i$).

IV. DISCUSSION

IV-1 Data Analysis

The data were analyzed statistically first to determine whether those living in the different areas showed significant differences either in CRI symptoms or in FEV that could be attributed to exposure to NO_2, and second to derive estimates of the prevalence of CRI in sub-populations, e.g., males, smokers, etc.

IV-2 Effects of exposure to NO_2

To determine whether there were significant differences in severity of CRI symptoms, a multivariate multiple regression analysis was done on unweighted data, treating CRI severity rating and FEV as dependent variables, treating height, age, sex, race, and alveolar CO level as regression variables, and treating area of residence and smoking habits as main effects. Thus the effects of exposure to NO_2 were corrected for the effects of these other variables. Estimates of effects obtained in the regression analyses are unbiased and tests of their significance are conservative.

Certain factors were not taken into account in the regression analysis. These include the type of heating system employed in the home, the family income level, the use of air conditioning, and the previous place of residence. These factors are assessed somewhat less quantitatively by comparisons of the sub-populations involved, and are discussed in IV-6, IV-7, and IV-8.

The effects of exposure to NO_2 were estimated using regression analysis based upon the model:

$$(A)\quad \underline{Y} = \mu + \sum_{i=1}^{\ell} \Theta_i \tau_i + \sum_{k=1}^{m} \alpha_k \gamma_k + \sum_{j=1}^{n} \beta_j X_j + \varepsilon$$

where:

Y is the estimated FEV, or CRI severity rating, depending upon which characteristic is analyzed; θ_i is 1 if the person lives in area i, or 0 if not; τ_i is the main effect of living in area i; α_k is 1 if the person has smoking habit k, or 0 if not; γ_k is the main effect of smoking habit; β_j is the effect of independent variable j; X_j is the measured value of variable j; ϵ is the uncontrollable error. Main effects and regression coefficients were estimated using an IBM-360/75 computer, and tested to determine which were significantly greater than zero.[15/] The main effects of exposure to NO_2 were estimated subject to the restriction:

$$\tau_\ell = \sum_{i=1}^{\ell-1} \tau_i$$

This is equivalent to the restriction:

$$\sum_{i=1}^{\ell} \tau_i = 0,$$

insofar as comparisons of one exposure level with another are concerned.

The results of the application of this model to the data are shown in Tables III, IV, and V. In the total population, CRI severity ratings were found to increase significantly with age ($p = 0.09$) and with smoking rate ($p = .0001$).* Females showed a significantly lower severity rating than males. When these effects were taken into account, there was no significant difference in symptom severity rating among the different study areas ($p = 0.3$ for study Phases 1 and 2; $p = 0.36$ for all phases).

After correction for the highly significant effects of smoking rate, height, age, sex, race, and CO level, persons in the high NO_2 area showed about 0.1 liter lower FEV than those in the other areas. ($p = 0.001$)

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* p is the probability of occurrence of the observed main effect or regression coefficient if the true value were zero.

that exposure to NO_2 results in a decreased FEV that is not accompanied by increased severity rating of cough or phlegm. The measurement of FEV is, of course, much more straight forward than the severity rating of CRI, and a change in FEV is readily detected. A change in the duration of cough or phlegm might or might not change the CRI severity rating, however. It would depend upon whether the increase changed the duration from less than three months to greater than three months. The rather low coefficient of correlation between FEV and CRI, -0.13, may be due in part to the lag in response of the severity rating of actual changes in the duration of symptoms. It is doubtful whether a respondent whose symptoms endure for a time very close to 3 months can recall accurately whether his duration is indeed greater than or less than three months. This uncertainty may also influence the coefficient of correlation.

IV-3 Exposure to Irritating Smoke, Dust or Fumes

The regression model was applied to a selected sub-population of those who had been or are exposed to irritating smoke, dust or fumes at work. Members of this sub-population indicated that they had been exposed to coal dust, or cutting oils, or chemical fumes, or dust and fibers from textile manufacturing for one year or longer. There were 168 persons in the group whose previous job involved exposure. Analysis of the data for this group showed differences in FEV among the study areas not to be significant ($p = 0.85$), but CRI was significantly lower in the High NO_2 and Outside Study Areas, than in Control Areas 1, 2, and the High Particulate Area. These results are shown in Table IV. This finding is based upon a very small sample, with no distinction of the different types of dust or fumes to which the different sub-populations were exposed. Residents of the intermediate exposure area continue to be exposed to a higher level of soiling index than those living in the High NO_2 Area, and this may be a factor.

TABLE III

Regression Model Applied to FEV and CRI Severity Ratings
Main Effects and Regression Coefficients

	Phases I and 2				All Phases	
	FEV, liters/sec		CRI, 1 to 7		CRI, 1 to 7	
	Value	Signif. Level	Value	Signif. Level	Value	Signif. Level
Mean Value	3.54		4.28		2.76	
NO_2 EXPOSURE AREA EFFECTS						
High NO_2	-0.086		0.024		0.059	
*Control Area 1a	0.017		0.103		0.064	
Control Area 1b	-0.019		0.103		0.107	
Control Area 2a	0.024	0.001	-0.101	0.3	-0.075	0.36
Control Area 2b	0.047		-0.257		-0.200	
High Particulate	0.017		0.194		0.074	
Outside Study	0.0015		-0.065		-0.028	
SMOKING CLASS EFFECTS						
Never smoked	0.28		-0.67		-1.05	
Quit smoking	0.24		-0.78		-1.01	
Smoke <1/2 pk/day	0.12	0.0001	-0.50	0.0001	-0.57	0.0001
Smoke 1/2 pk/day	0.048		-0.54		-0.39	
Smoke 1 pk/day	-0.10		0.45		0.48	
Smoke 1 1/2 pk/day	-0.23		0.82		1.13	
Smoke ≥2pk/day	-0.37		1.21		1.41	
REGRESSION COEFFICIENTS						
Height (ft.)	0.29	0.0001				
Age (years)	-0.025	0.0001	-0.0067	0.65	0.0083	0.09
Sex (male=1 female-2)	-0.79	0.0001	-0.279	0.008	-0.196	0.007
Race (white-1 black=2)	-0.22	0.009	-0.046	0.85	-0.0096	0.94
CO level (ppm)	0.0040	0.004	0.018	0.0002		

*Control areas 1a and 2a are the central portions of these control areas; 1b and 2b, their peripheries.

Of the 585 persons whose present employment involved exposure to smoke, dust or fumes, no significant differences in CRI severity rating were shown due to NO_2 exposure, age, sex, or race. The effects of smoking habits were significant for this group ($p = 0.0001$). A portion of these 585 persons, 304 in number, took the lung function test (FEV). No significant effect of NO_2 exposure level was shown among them. These results are given in Table V.

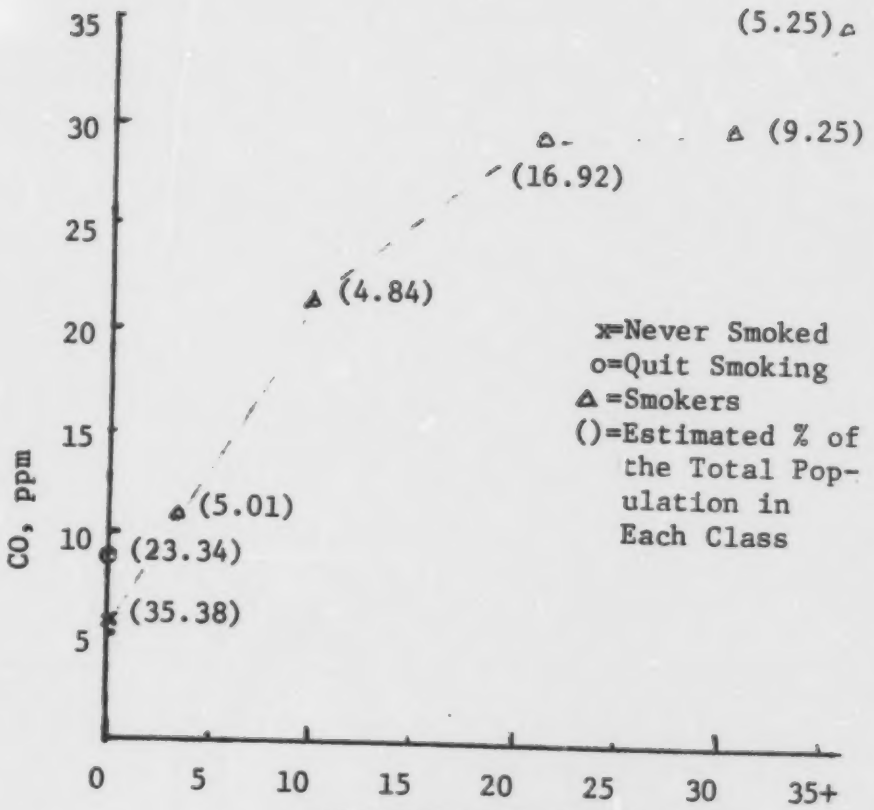

Figure 4. Carbon Monoxide Level in Breath vs. Smoking Rate

IV-4 Relation of Breath CO to Smoking Habits

As shown in Figure 4, the CO level in the breath and the smoking rate are linearly related up to a smoking rate of 1 pack of cigarettes per day (20 cigarettes). Beyond this rate of smoking, the CO level tends to remain below 35 ppm. CRI severity rating increased significantly with increases in CO level ($p = 0.0002$). The CO measurements were not made in Phases 3 and 4 of the study, and therefore this effect is not shown in Table III for the regression analysis on all phases.

TABLE IV

Regression Model Applied to Those Exposed to Irritating Smoke, Dust or Fumes in a Previous Employment (168 persons)

Main Effects and Regression Coefficients

	Max FEV, liters/sec		CRI, 1 to 7	
	Value	Signif. Level	Value	Signif. Level
Mean Value	3.30		5.41	
NO_2 EXPOSURE AREA EFFECTS				
High NO_2	0.012		-0.37	
Control Area 1	0.051		0.38	
Control Area 2	-0.081	0.85	-0.15	0.09
High Particulate	0.080		0.84	
Outside Study	-0.062		-0.71	
SMOKING CLASS EFFECTS				
Non Smoker	0.17	0.03	-0.71	0.004
Smoker	-0.17		0.71	
REGRESSION COEFFICIENTS				
Height (ft.)	0.21	0.003		
Age (years)	-0.0078	0.3	-0.028	0.23
Sex (male=1 female=2)	-0.805	0.0001	-0.39	0.27
Race (white=1 black=2)	0.150	0.5	-0.79	0.22
CO level (ppm)	0.0023	0.6	0.0072	0.65

TABLE V

Regression Model Applied to Those Exposed to Irritating Smoke, Dust or Fumes in Their Present Employment (585 persons)

Main Effects and Regression Coefficients

	Max FEV, liters/sec		CRI, 1 to 7	
	Value	Signif. Level	Value	Signif. Level
Mean Value	3.05		2.63	
NO_2 EXPOSURE AREA EFFECTS				
High NO_2	-0.03		0.0008	
Control Area 1a	-0.01		0.30	
Control Area 1b	0.18		0.087	
Control Area 2a	0.045	0.8	-0.23	0.64
Control Area 2b			-0.21	
High Particulate	-0.023		0.14	
Outside Study	-0.10		-0.08	
	-0.057			
SMOKING CLASS EFFECTS				
Never Smoked	0.29		-0.98	
Quit Smoking	0.41		-1.14	
Smoke < 1/2 pk/day	0.25		-0.74	
Smoke 1/2 pk/day	-0.17	0.0001	-0.33	0.0001
Smoke 1 pk/day	-0.027		0.24	
Smoke 1 1/2 pk/day	-0.21		1.04	
Smoke ≥ 2 pk/day	-0.55		1.91	
REGRESSION COEFFICIENTS				
Height (ft.)	0.45	0.0001		
Age (years)	-0.037	0.0001	0.011	0.65
Sex (male=1 female=2)	-0.68	0.0001	0.23	0.3
Race (white=1 black=2)	-0.31	0.03	-0.062	0.85
CO level (ppm)	0.0035	0.19		

IV-5 Prevalence of Chronic Respiratory Illness in Sub-populations

To compare the prevalence of CRI in the different study areas, and to compare other sub-populations (e.g., smokers vs non-smokers), a two-point rating was used (11-4), and weights were assigned to each individual so that unbiased estimates of the sub-population prevalence could be obtained. The weights depend upon the frequencies appearing in each school-phase-subgroup, and certain population totals, as shown by the following formula for calculation of T_{sp}, the total number in a sub-population:

$$(B)\quad T_{sp} = \Sigma X_1 + \lambda \frac{N-n_1}{n_2} \Sigma X_2 + (1-\lambda)\left\{ \frac{N-n_1}{N-n_1-n_2} \Sigma X_3 + \frac{(N-n_1)(N-n_1-n_2-n_3)}{} \Sigma X_4 \right\},$$

where each sum, ΣX_i, is over the number of persons in sample Phase i who qualify for the sub-population. The coefficients for Phases 2, 3 and 4 are the product of a factor involving an arbitrary constant λ and the weight assigned to the individual. N is the total population of parents of the students at a school; n_1, n_2 and n_3 are the number of respondents for Phases 1, 2 and 3 of the sampling frame. The factor λ is necessary to weight the two measures of the Phase 1 non-respondents (Figure 3) provided by the n_2 samples of Phase 2 and the combined samples of Phases 3 and 4. The number of respondents in each phase are given in Table VI. Values of λ, calculated so as to minimize the variance of the desired estimates, and the assigned weights are also given.

TABLE VI

Number of Respondents for Each Sampling Phase According to School and Sex

Sampling Phase	School										
	Central		Brainerd		Tyner		Red Bank		Total		
	M	F	M	F	M	F	M	F	M	F	Both Sexes
1	134	162	247	282	196	201	252	261	829	906	1735
2	35	33	34	42	38	37	30	35	137	147	284
3	130	143	196	233	102	112	114	126	542	614	1156
4	46	43	43	50	41	44	42	47	172	184	356
Sample	345	381	529	607	377	394	438	469	1680	1851	3531
Population	754	838	963	1125	736	791	818	887	3271	3641	6912

M = Male
F = Female

With the weights assigned as shown in (B), the estimated average for sub-population r, $\hat{\mu}_r$, was computed as follows:

(C) $$\hat{\mu}_r = \sum_{i=1}^{n_r} W_i X_i / \sum_{i=1}^{n_r} W_i,$$

where, if CRI is the variable of interest, X_i is 1 for its presence and 0 for its absence. W_i is the weighting factor. The weighting factors are w_1 and w_2 for physical tests. They are w_1, λw_2, $(1-\lambda)w_3$, and $(1-\lambda)w_4$ for the questionnaire responses. These are shown in Table VII.

TABLE VII

Weights, w_i, and Values of λ Assigned to the Study Participants

Phase		Central		Brainerd		Tyner		Red Bank	
		M	F	M	F	M	F	M	F
1	w_1	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
2	w_2	17.714286	20.484848	21.058824	20.071429	14.210526	15.945946	18.866667	17.885714
3	w_3	1.059829	1.051322	1.049853	1.052434	1.075697	1.066908	1.055970	1.059222
4	w_4	10.483092	12.224674	11.865785	11.955655	10.494607	10.693326	10.609986	10.479533
λ for questionnaire responses		0.321378	0.322246	0.293712	0.304415	0.376494	0.3541436	0.312556	0.321402
λ for physiological measurement		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000

M = Male

F = Female

Since the numerator and denominator are both random variables, this is a ratio type estimator and its approximate variance is given by:

$$(D)\quad \hat{V}(\hat{\mu}_r) = \frac{n_r}{\left(\sum_{i=1}^{n_r} W_i\right)^2 (n_r - 1)} \left\{ \sum_{i=1}^{n_r} (W_i X_i - \hat{\mu}_r W_i)^2 \right\}$$

$$= \frac{n_r}{\left(\sum_{i=1}^{n_r} W_i\right)^2 (n_r - 1)} \left\{ \sum_{i=1}^{n_r} W_i^2 X_i^2 - 2\hat{\mu}_r \sum_{i=1}^{n_r} W_i^2 X_i + \hat{\mu}_r^2 \sum_{i=1}^{n_r} W_i^2 \right\}$$

In case the X_i's are 0, 1 variables (e.g., when the variable is CRI) then the variance formulas simplify to:

$$(E)\quad \hat{V}(\hat{\mu}_r) = \frac{n_r}{\left(\sum_{i=1}^{n_r} W_i\right)^2 (n_r - 1)} \left\{ (1 - 2\hat{\mu}) \sum_{1}^{n_r} W_i^2 X_i + \hat{\mu}_r^2 \sum_{i=1}^{n_r} W_i^2 \right\}$$

and this depends only on the sums and sums of squares for the total sub-population and for those in the sub-population who have CRI, respectively.

Formulas (C), (D), and (E) were applied in the preparation of Tables VIII to XVII. Beginning in Table X, only population estimates, made using weighted data, are given. These are indicated as estimated values, that is, estimated percent, or estimated prevalence.

The prevalence of CRI found in each sample phase is shown in Table VIII. The variation in prevalence of CRI shown from sample phase to sample phase demonstrates the need for applying weights and computing a single estimate for each area. Table IX shows the prevalence of CRI, by study area, obtained by properly weighted estimates. For comparison, the prevalence obtained by direct computation from the samples is also shown. In both cases, CRI, defined by severity ratings 4 to 7, is not more prevalent in the high NO_2 exposure area than in the other areas.

TABLE VIII

Prevalence of Chronic Respiratory Illness in Each Sample Phase

Percent Showing Severity Rating 4 to 7

Sampling Phase	High NO_2 Area	High Particulate Area	Control Area 1	Control Area 2	Outside of Study Area
1	26(111)*	30(42)	28(351)	22(366)	26(54)
2	20(17)	36(5)	34(52)	12(51)	22(10)
3	32(91)	28(26)	23(303)	23(177)	25(38)
4	25(15)	27(15)	40(49)	30(58)	27(20)
All	27(234)	29(88)	28(755)	23(652)	25(122)

* Number in the sample showing severity rating of 4 or greater.

TABLE IX

Prevalence of Chronic Respiratory Illness, Severity Rating 4 to 7, Among Parents Who Live or Work in the Designated Study Area, Comparing Weighted and Unweighted Estimates

	High NO_2 Area	High Particulate Area	Control Area 1		Control Area 2		Outside Study Area
			a	b	a	b	
Weighted Estimates, %	24.5	28.5	33.5	32.9	34.8	26.1	25.2
Unweighted Estimate, %	27.3	29.2	27.5	27.8	24.0	20.2	25.1

Table X shows the estimated prevalence of the most severe CRI (severity rating 6 and 7 only), the standard deviation of the estimates, and the sample size on which they are based.

TABLE X

Estimated Prevalence of Chronic Respiratory Illness, Severity Rating 6 and 7, Among Parents Who Live or Work in the Designated Study Areas

	High NO_2 Area	High Particulate Area	Control Area 1	Control Area 2	Outside of Study Area
Chronic Respiratory Illness, %	13	16	20	11	13
Std. error	1.6	3.1	2.1	1.6	2.4
Sample size, number of persons	894	297	1,022	833	485

The smoking habits in the different areas are compared in Table XI. No significant differences were shown. In all areas, CRI was more prevalent among smokers than non-smokers. Those who had quit smoking showed approximately the same prevalence as those who never smoked. (Table XII).

IV-6 Chronic Respiratory Illness by Income Levels

Four ranges of annual income were selected, based upon census data and projected increases, to classify respondents into four economic categories. Participants were asked to indicate the class that applied to them. This was known to be a sensitive question, therefore, participants were told they could elect not to answer this one question. (No other question was afforded this option). Many chose not to disclose their income level. No significant difference in prevalence of CRI among income classes was found, nor did the non-respondents differ significantly in CRI from the respondents (Table XIII). The significant difference between smokers and nonsmokers is evident for all income levels.

TABLE XI

Estimated Proportions According to Smoking Habits, by Study Area

(Includes Those Who Live or Work in Designated Area)

	High NO_2 Area		High Particulate Area		Control Area 1		Control Area 2		Outside of Study Area	
	*		*		*		*		*	
Never Smoked	37	2.9	28	4.0	37	2.4	39	3.0	45	3.0
Quit Smoking	25	2.4	28	4.0	23	1.9	25	2.0	19	3.0
Smoke < 1/2 pk/day	5.3	1.3	4	1.7	3.7	1.0	2	0.7	4	1.4
Smoke 1/2 pk/day	5.8	1.3	10	2.8	7.2	1.4	5	1.0	6	1.5
Smoke 1 pk/day	14	1.8	17	3.4	17	2.0	16	2.0	16	3.0
Smoke 1 1/2 pk/day	6.5	1.4	7	2.0	7	1.3	7	1.4	6	1.7
Smoke 2 pk/day	6	1.3	6	2.0	4	1.0	6	1.4	4	1.4
Total Est. Pop.	1581		698		1915		1574		1144	

* The first number is the percent; the second, its standard deviation.

TABLE XII

Estimated Prevalence of CRI Severity Rating 4 to 7 by Study Area, Sex, and Smoking Habits

	MALES			FEMALES		
	Never Smoked	Quit	Smoking	Never Smoked	Quit	Smoking
High NO_2 Area, %	19	14	43	17	23	32
Control Area 1, %	6	29	64	21	17	41
Control Area 2, %	14	17	50	10	4	35
High Particulate Area, %	15	17	31	17	6	28
Outside Study Area, %	27	22	51	17	6	29

TABLE XIII

Estimated Prevalence of Chronic Respiratory Illness Severity Rating 4 through 7 by Smoking Status and Annual Income

	Non Smokers			Smokers		
Annual Income	Number in Sample	Prevalence of CRI, %	Standard Deviation	Number in Sample	Prevalence of CRI, %	Standard Deviation
Not Reported	1065	18	2.0	601	46	3.0
< $4500	32	17	6.5	24	49	1.5
$4500 to $7999	140	14	3.8	62	46	8.5
$8000 to $10999	325	15	2.7	133	39	5.9
$11000 or more	820	15	1.6	329	45	3.9

IV-7 Chronic Respiratory Illness by Methods of Heating and Cooling

Table XIV shows the prevalence of CRI by area and by type of fuel for both central and non-central heating. Effects of smoking habits are not taken into account. Electric heating is the predominant method, and persons in Control Area 1 using non-central electric heating showed a significantly higher prevalence of CRI than those in other areas using the same method.

Persons outside the study areas using central heating with coal and those in Control Area 1 using non-central heating with oil showed the highest prevalence of CRI. Within Control Area 1, those using central gas heat showed significantly greater prevalence of CRI than those using electric heat. This difference was not shown in Area 2.

Table XV shows the prevalence of CRI by area and use of air conditioning. Those without air conditioners in the high NO_2 exposure area showed significantly lower prevalence than those in the same area using either window or central air conditioners. The same effect is shown in Control Area 2. No significant differences were shown in the other areas.

IV-8 Chronic Respiratory Illness by Place of Residence

The prevalence of CRI was not significantly different among those who had lived in the study areas most of the time since they were thirty years of age and those who had lived elsewhere. (Table XVI).

IV-9 Forced Expiratory Volume, FEV

When corrected for height, age, sex, smoking habit, and CO level, FEV was lower in the High NO_2 Area than in the other areas. Table XVII shows the average FEV, by area, age, and sex, for present smokers and non-smokers. Non-smokers include both those who never smoked, and those who have quit. "Smokers" includes all rates from less than 1/2 pack of cigarettes per day to more than 2 packs per day.

TABLE XIV

Estimated Prevalence of Chronic Respiratory Illness, Percent with Severity Ratings 4 through 7

by Type of Heating System and Kind of Fuel Used in Present Living Quarters

Study Section and Heating System	Type of Fuel																	
	Coal			Oil			Gas			Elec.			Other			All Fuels		
	*			*			*			*			*			*		
High NO_2 Area																		
Central Heating				19	29	16	70	24	8.3	264	27	4.2	2	50	50	364	27	3.6
Non Central Heating	15	12	9	9	23	16	6	4	5	433	24	3				466	23	29
High Particulate Area																		
Central Heating	3	33	33													13	9.5	6.9
Non Central Heating							11	2.7	3	28	23	13				41	22	10
Control Area 1																		
Central Heating	18	7.4	16	36	35	1.4	132	39	6.5	259	27	4.6				449	32	3.6
Non Central Heating	16	36	21	7	72	21	33	21	13	488	37	4				545	37	3.4
Control Area 2																		
Central Heating	9	49	22	24	27	15	87	26	7	141	26	5.8				263	28	4
Non Central Heating	25	21	14				26	9.2	5.4	482	23	3	12	61	21	565	22	2.7
Outside Study Area																		
Central Heating	4	77	24	12	66	19	25	33	14	275	27	4				321	29	4.1
Non Central Heating	23	9.4	6.1	15	18	11	10	7.3	6.1	449	26	3	4	19	21	501	24	3.7

* The first number is the sample size; the second is the prevalence of CRI, %; the third, the standard error.

TABLE XV

Estimated Prevalence of Chronic Respiratory Illness Severity Rating 4 through 7 According to Use of Air Conditioning in Present Living Quarters

	Air Conditioning In Present Living Quarters								
	None			Window			Central		
Section	Number	% CRI	SD	Number	% CRI	SD	Number	% CRI	SD
High NO_2	94	16	5.4	419	26	3.0	317	27	3.9
High Particulate	14	18	12.0	40	20	10.0			
Control Area 1	92	31	7.9	610	37	3.2	291	32	4.6
Control Area 2	159	17	4.0	480	27	3.1	182	26	5.3
Outside Study Area	129	25	5.1	437	25	3.1	256	27	4.4

TABLE XVI

Estimated Prevalence of Chronic Respiratory Illness Severity Rating 4 through 7 Among Parents vs Place of Residence for Most of the Time Since They Were Thirty Years Old

Lived Most of the Time Since Age 30 In:	Number in Sample	Prevalence of CRI, %	Standard Deviation
Chattanooga:			
High NO_2 Area	503	25	2.8
High Particulate Area	121	31	6.7
Control Area 1	674	35	3.1
Control Area 2	507	25	3.1
Vicinity of Chattanooga Not in Study Area	1,094	25	2.0
Different Area:			
Population 200,000	123	25	6.2
Population 50,000 - 200,000	216	26	4.8
Population 50,000	219	24	4.8
Rural Area (Farm)	50	32	10.0

TABLE XVII

Estimated Average FEV by Study Area, Age, Sex and Smoking Habits

High NO_2 Area	30-39 #	30-39 FEV	30-39 SD	40-49 #	40-49 FEV	40-49 SD	50-59 #	50-59 FEV	50-59 SD
Males									
Do Not Smoke	27	3.53	0.36	99	3.12	0.14	29	2.60	0.30
Smoke	11	2.98	0.18	50	2.60	0.16	21	2.29	0.09
Females									
Do Not Smoke	63	2.34	0.10	100	2.40	0.09	25	2.36	0.13
Smoke	29	2.13	0.06	42	2.18	0.09	4	0.24	0.28
High Particulate Area									
Males									
Do Not Smoke	10	3.34	0.12	40	3.21	0.08	13	3.21	0.21
Smoke	10	3.09	0.05	24	2.56	0.26	6	2.86	0.07
Females									
Do Not Smoke	18	2.34	0.03	15	2.50	0.07	3	2.27	0.14
Smoke	2	2.70	0.40	7	2.40	0.13			
Control Area 1									
Males									
Do Not Smoke	9	2.54	0.22	110	3.11	0.10	51	3.03	0.14
Smoke	14	2.69	0.17	50	2.41	0.15	21	2.22	0.17
Females									
Do Not Smoke	43	2.14	0.07	132	2.36	0.07	42	1.86	0.12
Smoke	24	2.26	0.09	47	1.82	0.26	14	1.77	0.12
Control Area 2									
Males									
Do Not Smoke	32	3.67	0.39	93	3.38	0.12	38	3.18	0.12
Smoke	16	2.92	0.18	56	2.88	0.12	15	2.65	0.18
Females									
Do Not Smoke	74	2.47	0.08	120	2.38	0.08	28	2.07	0.08
Smoke	15	2.31	0.14	27	1.90	0.17	6	1.64	0.05
Outside Study Area									
Males									
Do Not Smoke	5	3.54	0.24	38	2.66	0.31	12	3.06	0.19
Smoke	6	3.01	0.14	21	2.34	0.59	8	2.01	0.22
Females									
Do Not Smoke	40	2.29	0.17	72	2.18	0.17	15	1.81	0.29
Smoke	11	2.29	0.19	21	1.93	0.11	4	1.53	0.59

V. CONCLUSIONS

At the time of this study, portions of the population had been exposed to the levels of NO_2 shown herein for a period of four years. FEV among those living in the high NO_2 exposure area was shown to be lower than in the other study areas ($p = 0.001$). This effect was found after removal of the effects of six other factors: smoking habits, height, age, sex, race, and the CO level of alveolar breath. No significant difference in the severity of CRI symptoms, or in the prevalence of definite chronic respiratory illness was shown among the study areas.

The FEV is a timed vital capacity measurement and is presumably a suitable test for detecting chronic obstructive and restrictive lung abnormalities in mass screening. It shows a correlation coefficient of -0.13 with the CRI severity ratings obtained in this study. Therefore, the occurrence of an effect on FEV without an effect on CRI is a reasonable finding. At the concentrations met in the high NO_2 area, the effect of NO_2 exposure is a reduction in FEV of about 100 millileters, with insignificant increase in presistence of cough or phlegm.

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APPENDIX A

DESCRIPTION OF BOUNDARIES OF AREAS CHOSEN FOR STUDY

Reference: Map of Chattanooga, Avis, 1029 Market Street, Chattanooga

HIGH NO_2 AREA

This area is bounded on the north by Chickamauga Lake; on the east by a line extending south from a point 1/4 mile east of Fythian road to intersect with Interstate 75 just beyond Silverdale; on the south by Interstate 75; on the west by highway 153.

Control Area 1

This area is bounded on the north by Glass Street, beginning at its intersection with N. Chamberlain Avenue, and running east to the city limits and to Shallowford Road at Chickamauga Creek, and along a line east to Airport Road. On the east, the boundary is the N. C. and St. L. Ry. to the city limits at Chickamauga Creek. The south boundary is Chickamauga Creek west to Interstate 75, thence southwest to Spring Creek Road, and along Spring Creek Road to Oakdale Avenue, west along Oakdale, Covington, and Parham to Claremont, around Mt. Olivet Cemetary to Pinellas and Buchanan Streets, intersecting Interstate 24, and ending at the intersection of Dodds Avenue and E. 18th Street. The west boundary is Dodds Avenue to Glenwood Drive to Chamberlain Avenue, thence to the starting point.

Control Area 2

This area is bounded on the north by the intersection of Edwards Point Road and Shackleford Road at Signal Mountain, thence due east to

highway 153. The eastern boundary runs due south from the intersection to Nick-a-Jack Lake, and along the Tennessee river to the city limits. The south boundary is the city limits to Cherokee Boulevard, then to Dayton Avenue. The western boundary follows Signal Mountain Road (Rt. 8) to Route 27, and continues along Route 27 to a point due south of the starting point (the intersection of Edwards Point Road and Shackleford Road), then runs north to the starting point.

High Particulate Area

This area is the downtown Chattanooga section bounded on the west and north by the Tennessee River and Glass Street, on the east by N. Chamberlain Avenue, Glenwood Drive and Dodds Avenue; on the south by the state line to St. Elmo Avenue thence to W. 36th Street, and across Craven Yards to the Tennessee River.

APPENDIX B

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School Number _____

Identification Number 6966

Budget Bureau No. 85-R0133

RESPIRATORY CONDITION STUDY

conducted by

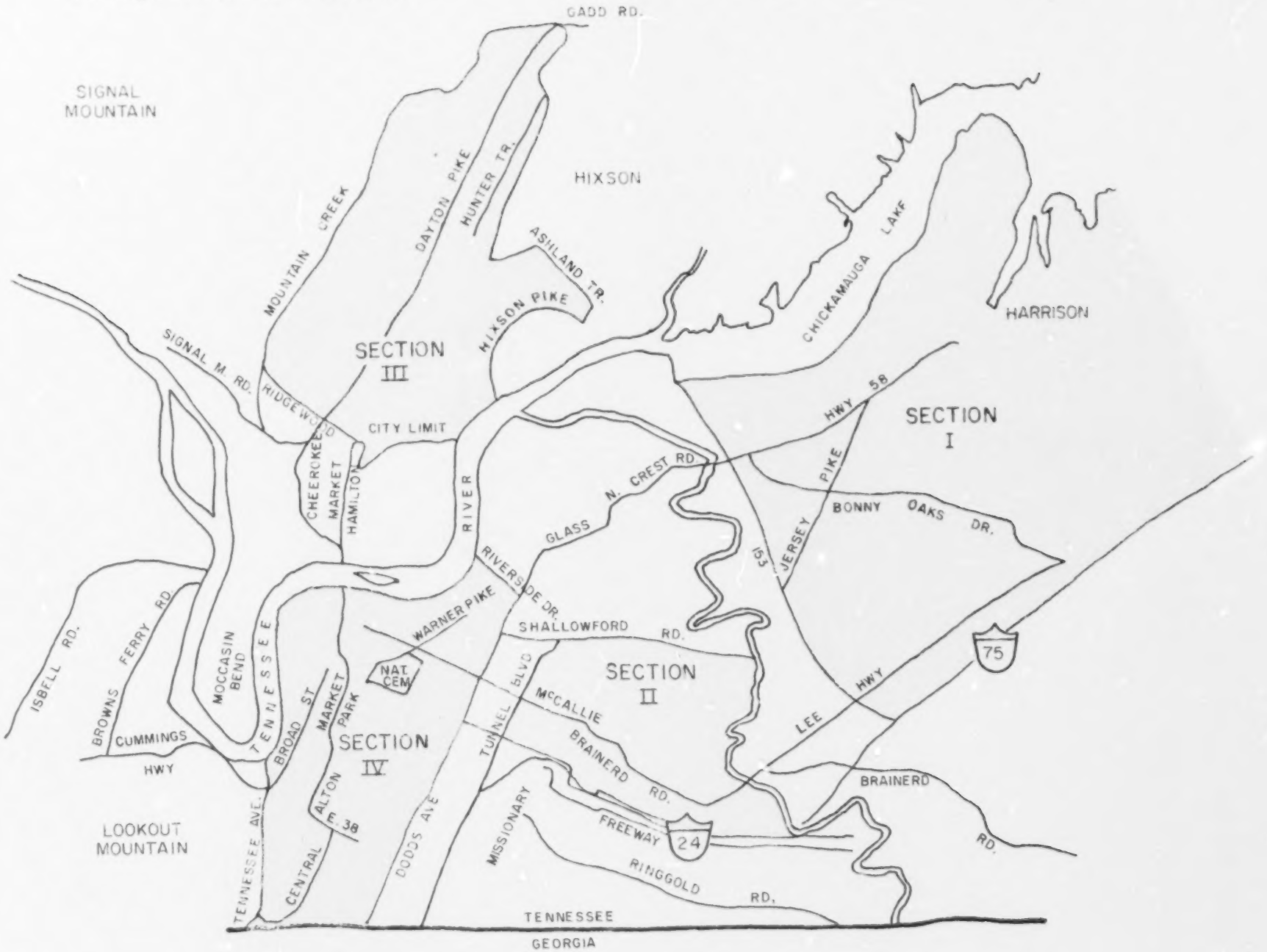
The Research Triangle Institute
Research Triangle Park, N. C.

1. Name _____
Last First Middle

RESPIRATORY CONDITION STUDY

CHATTANOOGA MAP

Showing Sections and Boundaries



SCHOOL NUMBER	IDENTIFICATION NUMBER
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⬭	⬭⬭⬭⬭
⬭	⬭⬭⬭⬭
⬭	⬭⬭⬭⬭
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THE ANSWERS GIVEN HERE WILL BE USED FOR RESEARCH PURPOSES ONLY AND WILL BE KEPT CONFIDENTIAL.

INSTRUCTIONS

Please answer all questions. For most questions you may indicate your answer by filling in the proper oval. For the few questions that require a written response, please print your answers or write legibly. PLEASE USE A SOFT, LEAD PENCIL. DO NOT USE BALL-POINT PEN.

2. Please enter date of birth: Month_____, Year _____; and age _____ Yrs.

3. SEX

- ⬭ Male
- ⬭ Female

4. MARITAL STATUS

- ⬭ Currently married
- ⬭ Divorced
- ⬭ Separated
- ⬭ Widow/Widower
- ⬭ Never married

5. RACE

- ⬭ White
- ⬭ Negro
- ⬭ Other (specify) _____

Mo.	Year	Age
Jan ⬭	⬭⬭	⬭⬭
Feb ⬭	⬭⬭	⬭⬭
Mar ⬭	⬭⬭	⬭⬭
Apr ⬭	⬭⬭	⬭⬭
May ⬭	⬭⬭	⬭⬭
Jun ⬭	⬭⬭	⬭⬭
Jul ⬭	⬭⬭	⬭⬭
Aug ⬭	⬭⬭	⬭⬭
Sep ⬭	⬭⬭	⬭⬭
Oct ⬭	⬭⬭	⬭⬭
Nov ⬭		
Dec ⬭		

6. What is your present address? (Please give complete address including apartment number and zip code.)

_____
Street and number

_____
Town State Zip code

Please look at the map on page 2 and indicate the numbered section of the map in which you now live.

Section Number ⟶

SECTION	
I ⬭	III ⬭
II ⬭	IV ⬭

(If the section in which you live is not numbered on the map, fill in this oval ⬭.)

7. How long have you lived at your present address?

YEARS	MONTHS
0 0	0 0
1 1	1 1
2 2	2
3 3	3
4 4	4
5 5	5
6 6	6
7 7	7
8 8	8
9 9	9

_____ Years _____ Months

8. (a) Do you have air conditioning in your present living quarters?

○ Yes ○ No → Please skip to question 9

(b) What type of air conditioning do you have?

○ Window ○ Central

9. How do you heat your present living quarters? (Please mark main method.)

○ With coal

○ With oil

○ With gas

○ With electricity

○ Other - please specify _____

10. Do you have central heating in your present living quarters?

○ Yes ○ No

11. Where did you live during most of the time before you were 20 years old? (Please mark one.)

○ Chattanooga or vicinity, in one of the sections shaded on the map, page 2.

Mark Section Number →

Section	
I ○	III ○
II ○	IV ○

○ Chattanooga or vicinity, not numbered on map

○ Different city or area - Population greater than 200,000

○ Different city or area - Population between 50,000 and 200,000

○ Different area - A small city or town, less than 50,000

○ Different area - A rural area or farm

12. Where did you live during most of the time when you were between 20 and 30 years old? (Please mark one.)

- ⬭ Chattanooga or vicinity, in one of the sections shaded on the map, page 2.

  Mark Section Number →

Section	
I ⬭	III ⬭
II ⬭	IV ⬭

- ⬭ Chattanooga or vicinity, not numbered on map
- ⬭ Different city or area - Population greater than 200,000
- ⬭ Different city or area - Population between 50,000 and 200,000
- ⬭ Different area - A small city or town less than 50,000
- ⬭ Different area - A rural area or farm

13. Where have you lived during most of the time since you were 30 years old? (Please mark one.)

- ⬭ Not yet 30 years old
- ⬭ Chattanooga or vicinity, in one of the sections shaded on the map, page 2.

  Mark Section Number →

Section	
I ⬭	III ⬭
II ⬭	IV ⬭

- ⬭ Chattanooga or vicinity, not numbered on map
- ⬭ Different city or area - Population greater than 200,000
- ⬭ Different city or area - Population between 50,000 and 200,000
- ⬭ Different area - A small city or town, less than 50,000
- ⬭ Different area - A rural area or farm

14. Are you presently employed outside your home?

⬭ Yes → Please continue with 15 on the next page.

⬭ No → Please skip to question 19

15. (a) Do you work in Chattanooga or vicinity?

⬭ Yes → ⬭ No → Please skip to question 16

(b) Please indicate the numbered section of the map on page 2 in which you work.

Section Number →

Section	
I ⬭	III ⬭
II ⬭	IV ⬭

(If the section in which you work is not numbered on the map, fill in this oval ⬭ .)

16. Where does your job require you to work? (Please mark one.)

⬭ Mostly indoors ⬭ Mostly outdoors

17. (a) Do you operate a car or truck regularly as part of your job duties? (This does not include driving to and from work.)

⬭ Yes → ⬭ No → Please skip to question 18

(b) Where do you spend most of the time when you are working? (Please mark one.)

⬭ Within a 25-mile radius of Chattanooga

⬭ Outside a 25-mile radius of Chattanooga

18. (a) At your present job are you frequently exposed to irritating smoke, dust, or fumes?

⬭ Yes → ⬭ No → Please skip to question 19

(b) Which of the following irritants are you exposed to?

(Please mark as many as apply.)

⬭ Coal dust

⬭ Cutting oils

⬭ Chemical fumes - please specify _____

⬭ Dust and fibers from textile manufacturing

⬭ Other - please specify _____

(c) How long have you been exposed to these irritants?

- ⬭ Less than 1 year
- ⬭ 1 - 5 years
- ⬭ 6 - 10 years
- ⬭ More than 10 years

(d) What kind of work do you perform in your present job?

(For example, miner or factory machine operator.)

_____

JOB CODE

⬭ A ⬭ B

19. (a) Have you ever had a job (other than your present job, if now employed) at which you were frequently exposed to irritating smoke, dust, or fumes?

⬭ Yes ⬭ No ⟶ Please skip to question 20

(b) Which of the following irritants were you exposed to?

(Please mark as many as apply.)

- ⬭ Coal dust
- ⬭ Cutting oils
- ⬭ Chemical fumes - please specify _____
- ⬭ Dust and fibers from textile manufacturing
- ⬭ Other - please specify _____

(c) How long were you exposed to these irritants?

- ⬭ Less than 1 year
- ⬭ 1 - 5 years
- ⬭ 6 - 10 years
- ⬭ More than 10 years

(d) What kind of work did you perform in that job? (For example, miner or factory machine operator.)

_____

JOB CODE

(e) How long has it been since you worked at that job?

_____ years

YEARS

20. (a) Do you usually cough first thing in the morning in the winter?

(Count two or more coughs upon arising, or when you first go out-of-doors, or when you smoke the first cigarette of the day.)

○ Yes ○ No → Please skip to question 21

(b) Do you cough like this on most mornings for as much as three months each year?

○ Yes ○ No

21. (a) Do you usually cough during the day or night in the winter?

(Do not count an occasional cough.)

○ Yes ○ No → Please skip to question 22

(b) Do you cough like this on most days or nights for as much as three months each year?

○ Yes ○ No

22. (a) Do you usually bring up phlegm (thick fluid) from your chest first thing in the morning in the winter? (Count phlegm upon arising, or on first going out-of-doors, or with the first cigarette of the day, whether phlegm is swallowed or expelled. Do not count phlegm from nose.)

⬭ Yes ⬭ No → Please skip to question 23

(b) Do you bring up phlegm like this on most mornings for as much as three months each year?

⬭ Yes ⬭ No

23. (a) Do you usually bring up phlegm from your chest during the day or night in the winter? (Count twice or more.)

⬭ Yes ⬭ No → Please skip to question 24

(b) Do you bring up phlegm like this on most days or nights for as much as three months each year?

⬭ Yes ⬭ No

24. Do you get short of breath when you are walking with other people at an ordinary pace on a level surface?

⬭ Yes ⬭ No

25. (a) Have you ever smoked cigarettes?

⬭ Yes ⬭ No → Please skip to question 26

(b) Do you smoke cigarettes at the present time?

⬭ Yes ⬭ No → Please skip to question 26

Please continue with (c) on the next page.

(c) How many cigarettes do you usually smoke a day?

(Please mark one.)

- ⬭ Less than 1/2 pack (1 - 5 cigarettes)
- ⬭ About 1/2 pack (6 - 14 cigarettes)
- ⬭ About 1 pack (15 - 25 cigarettes)
- ⬭ About 1-1/2 packs (26 - 34 cigarettes)
- ⬭ About 2 or more packs (35 or more cigarettes)

26. Are you under treatment by a physician for a chronic respiratory condition, other than an allergy?

⬭ Yes ⬭ No

27. (a) Are you under treatment by a physician for any respiratory allergy?

⬭ Yes ⬭ No → Please skip to question 28

(b) To what are you allergic? (Please mark as many as apply.)

- ⬭ Pollen
- ⬭ Feathers
- ⬭ Dust
- ⬭ Tobacco smoke
- ⬭ Other - please specify _____

28. Do you currently have a new cold, cough, or sore throat?

⬭ Yes ⬭ No

RESPIRATORY CONDITION STUDY

We would like you to complete two simple tests as part of this study. One, the spirometer test, will measure your breath expulsion rate. The second uses a sample of your breath for analysis. We will be happy to advise your physician of the results of these tests if you wish.

Do you wish your physician to be notified of the test results?

☐ Yes ☐ No

Physician's name _____

Address _____

Street and Number

_____

City State

29. (a) How tall are you?

feet	inches
0	0
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9

_____ feet _____ inches

(b) What is your date of birth and age?

Month _____, Year _____; and age _____ Yrs.

30. Do you cough up phlegm from your chest on most days or nights for as much as three months each year?

○ Yes ○ No

31. What was your total family income for the year 1969?

○ A

○ B

○ C

○ D

32. Spirometer Tests

FEV 1.0

Test 1 Test 2

.	.
0	0
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9

33. Breath Analysis

CO_2 (ppm)

			.
0	0	0	0
1	1	1	1
2	2	2	2
3	3	3	3
4	4	4	4
5	5	5	5
6	6	6	6
7	7	7	7
8	8	8	8
9	9	9	9

APPENDIX C

RESPIRATORY CONDITION STUDY

Chattanooga, Tennessee

FIELD PROCEDURES

I. Development of a Mailing List and Initial Contacts

For the four senior high schools selected for participation in the study, it was necessary to compile a comprehensive and complete list of parent names and addresses, using the student card files at each school.

In order that alternative methods of data collection might be compared, one-half of the parents in each school were mailed a letter which requested that they complete a questionnaire which was enclosed and bring it with them to the school during a one week period in which interviewers would be available. The other half of the parents were not sent a questionnaire, but were asked to come into the school and complete the questionnaire after their arrival. All parents were asked to take two short lung function tests once they arrived at the school and completed the questionnaire. For one of the tests the respondent was asked to blow into a Stead-Wells spirometer for measurement of breath expulsion rate. For the other test, each was asked to breathe into a milar bag attached to a valve to separate and collect only alveolar air. The breath sample obtained in the milar bag was then analyzed to determine the carbon monoxide content.

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Interviewers and equipment were made available for one week at each of the four participating schools in turn. Parents were asked to come into the schools from 6:00 to 9:30 P.M. any evening during the week or Saturday morning from 9:00 to 12:00 noon. Participants who came into the schools were checked off on the original mailing list and those who did not have questionnaires were given questionnaires and assigned numbers. Each parent was then administered the questionnaire by an interviewer, each interview requiring 10 to 15 minutes. The spirometer test and breath analysis were then administered. A schedule showing the weeks in which the interviewer team was at each school is given in Table CI.

The study began at Central High School. Parents were informed of the study through letters mailed from RTI approximately one week in advance, and were reminded of the study again during the week through a REMINDER TO PARENTS form taken home by each student at the school. Newspaper, radio, and television publicity were all used early in the study, but word-of-mouth advertising did not take hold until later in the week. During the first nights at Central High School, only about 25 to 30 parents participated. However, toward the latter part of the week, participation improved a great deal and a total of 242 was reached for the week.

The second week was spent at Brainerd High School where participation was good all week and local publicity was excellent. A total of 449 parents participated in the study. Most parents thoroughly enjoyed the questionnaire and tests once they got to the school and additional photographs, interviews, etc., were made by the newspapers and television to add impetus to the participation. Due to this increased publicity,

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etc, it was decided to send another letter to the non-participants from the Central High School parent list and inform them that their participation was still needed. These parents were requested to come to Tyner High School the next week. Since Central High School and Tyner High School were fairly close together and many of the parents of students at Central lived close to Tyner, it was felt that we would have a good opportunity to pick up additional participants. This letter to Central High parents was mailed out about the middle of the week before we were to be at Tyner.

During our third week in the field at Tyner High School, fairly good results were obtained from the Tyner area parents (a total or 263 for the week) and an additional 61 parents from Central High School came in.

At Red Bank High the response was much like that at Brainerd, with a total of 325 participants for the week. This then concluded our initial study, but in order to give all parents a second opportunity to participate, we returned to Tyner High School. Letters were sent to non-participants at Tyner and Brainerd High Schools (also fairly close together) asking them to come in one evening during the week or on Saturday morning to take part in the study.

During the evenings we had interviewers and equipment at the schools for the second time. The hours were changed slightly to allow interested parents even more of an opportunity to participate. The school, newspapers, television, etc. all advertised the new hours of 5:00 P.M. to 9:00 P.M. This made it possible for many parents to stop at the school on the way home from work. During this revisit to Tyner High School, 116 more parents of Tyner students came in to participate, 80 additional Brainerd parents

came in, and 6 additional Central High parents came in. While this revisit to Tyner was being done, letters were sent out to all non-participants at Red Bank High School.

The revisit for one week at Red Bank brought in an additional 191 parents for a total of 516 for the two weeks spent there.

II. Household Interview Sample and Follow-up

Following one week of interviewing etc, at each of the four high schools and two additional follow-up weeks to give parents another opportunity to participate, it was necessary to select a sample of non-respondents. This sample was to represent all those who had failed to appear. The parents in this sample of approximately 50 households per school were called on personally and asked to complete the questionnaire and two breath tests in their homes. The sample was selected on the basis of three non-respondent categories: (1) both parents not responding (2) male parent only not responding and (3) female parent only not responding. The largest number of households of these three categories was the first, in which neither parent had responded. As a result, for most of the households in the personal interview sample both parents were requested to complete the questionnaire and tests.

The interviewers used for the personal interview portion of the study were the male staff used in the schools to complete questionnaires and tests. Most of the work was conducted during the evening hours and several of the interviewers were asked to carry around the large drum-type spirometers used in the school. One portable spirometer was used during this phase of the

study and it had to be passed back and forth among interviewers. There were approximately 100 individuals selected in this sample from each of the schools and a total of 285 individuals actually took part in the home interview sample portion of the study. There were 67 participants from Central, 75 from Brainerd, 78 from Tyner, and 65 from Red Bank. Complete results are shown in Table CI.

III. Mail Return Follow-up

After the selection of the household interview sample, all other non-respondents at each school were asked to complete and return a questionnaire by mail. All parents who had been mailed questionnaires initially were asked to complete the questionnaire and mail it in using a postage-paid envelope which we enclosed. They were also told that if the questionnaire originally mailed to them had been misplaced or destroyed that they could get another one simply by calling the Chattanooga-Hamilton County Health Department. All parents who had not been sent questionnaires originally, were sent questionniares and postage-paid envelopes for mailing them back. Although many of the participants did not take a great deal of time and effort in completing their questionnaires, the number of questionnaires returned by mail was quite good. There were a total of 269 mail returns at Central High School. 400 at Brainerd, 206 at Tyner, and 225 at Red Bank. See table on page C8 for complete results.

IV. Telephone Sample of Non-respondents

One last sample to represent those who failed to mail in complete returns was then drawn. This sample of approximately 100 parents per

school was to represent all those who did not mail in a completed questionnaire. For this sample of parents, the women of the original interviewing team were used. Here again, the results were quite satisfactory. Of the 100 parents at Central High, 91 were contacted by telephone and completed a questionnaire by personal interview on the telephone. At Brainerd High, 93 of the 100 parents in the sample were contacted and completed an interview over the telephone. At Tyner High 85 of 100 completed a questionnaire by telephone and 89 of 100 at Red Bank completed a questionnaire by telephone.

Table C II points out the actual numbers and percentages of parent participation in the various phases of this study, and details the reasons for non-response.

TABLE CI

STUDY OF CHRONIC RESPIRATORY DISEASE PREVALENCE IN CHATTANOOGA, TENNESSEE

Schedule for Data Collection

October 5-10, 1970	- Central High School Interviewers and equipment at the school for parents to come in.
October 12-17, 1970	- Brainerd High School Interviewers and equipment at the school for parents to come in.
October 19-24, 1970	- Tyner High School Interviewers and equipment at the school for parents to come in, and follow-up for parents at Central High School.
October 26-31, 1970	- Red Bank High School Interviewers and equipment at the school for parents to come in.
November 2-7, 1970	- Tyner High School Interviewers and equipment at the school for parents to come in; follow-up for parents at Brainerd and Tyner.
November 9-14, 1970	- Red Bank High School Interviewers and equipment at the school for parents to come in; follow-up for parents at Red Bank.
November 16-21, 1970	- Household Interview Sample for parents at Central High School. Follow-up Mailing to non-respondents at Central High School requesting mail return of questionnaire.
November 23-28, 1970	- Household Interview Sample for parents at Brainerd High School and Tyner High School and continue at Central. Follow-up Mailing to non-respondents at Brainerd and Tyner High Schools requesting mail return of questionnaires.
November 30 - December 5, 1970	- Household Interview Sample for parents at Red Bank High School and continue at Central, Brainerd, and Tyner. Follow-up Mailing to non-respondents at Red Bank High School requesting mail return of questionnaires.
December 7-12, 1970	- Telephone Interview Sample of non-respondents at Brainerd and Tyner High Schools.
December 14-19, 1970	- Telephone Interview Sample of non-respondents at Red Bank High School. Complete work at all stages of data collection.

TABLE CII

Chattanooga Air Pollution Study

RESULTS

RESPONSE	Central	Brainerd	Tyner	Red Bank	Total
Questionnaires From School Phase	299	529	392	517	1737
Complete With Both Tests	(290)	(436)	(382)	(477)	(1585)
No Tests	(9)	(9)	(10)	(6)	(34)
Spirometer Test Only	(0)	(84)	(0)	(33)	(117)
Breath Analysis Test Only	(0)	(0)	(0)	(0)	(0)
Questionnaires From Follow-up Mailing	269	400	206	225	1100
Questionnaires From Follow-up Mailing (AFTER CUT-OFF DATE)	2	29	8	12	51
Questionnaires From Home Interview Sample	67	75	78	65	285
Complete With Both Tests	(65)	(74)	(77)	(65)	(281)
No Tests	(2)	(1)	(1)	(0)	(4)
Spirometer Test Only	(0)	(0)	(0)	(0)	(0)
Breath Analysis Test Only	(0)	(0)	(0)	(0)	(0)
Questionnaires From Telephone Sample	91	93	85	89	358
TOTAL	728	1126	769	908	3531
NON-RESPONSE					
School Phase With No Tests	9	9	10	6	34
Brought In By Spouse	(5)	(7)	(5)	(2)	(19)
Mailed In	(3)	(2)	(3)	(3)	(11)
Refused	(1)	(0)	(0)	(0)	(1)
Other	(0)	(0)	(2)	(1)	(3)
School Phase With No Breath Analysis Test	0	84	0	33	117
Home Interview Sample Non-Response	33	26	22	35	116
Refused	(5)	(10)	(4)	(12)	(31)
Moved From Area	(1)	(1)	(4)	(4)	(10)
Unable to Locate Housing Unit	(13)	(2)	(3)	(4)	(22)
Not At Home	(12)	(11)	(8)	(12)	(43)
Mailed In	(2)	(0)	(0)	(3)	(5)
Temporarily Away	(0)	(2)	(3)	(0)	(5)
Telephone Interview Sample Non-Response	9	7	15	11	42
Refused	(2)	(2)	(4)	(2)	(10)
Moved From Area	(5)	(2)	(7)	(3)	(17)
No Phone	(2)	(3)	(2)	(2)	(9)
Mailed In	(0)	(0)	(2)	(3)	(5)
Unable To Reach	(0)	(0)	(0)	(1)	(1)